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6. AUTHOR(S)
Lawrence Carin

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Duke University
Department of Electrical and Computer Engineering
Durham, NC 27708-0291

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13. ABSTRACT (Maximum 200 words)

Algorithmic and sensor adaptivity will play a central role throughout the proposed research. The phenomenological links across multiple sensors are essential for utilizing the inversion results from one modality to constrain the inversion of data from another. In addition, this phenomelogical link will be important in employing results from multi-sensor inversion as feedback to the sensors, from which the sensors will autonomously and adaptively optimize themselves for a given sensing scenario. In this context we propose to exploit the fact that future DoD systems are likely to rely increasingly on robots and other unmanned vehicles. For example, with regard to the wide-area sensing problem, one can expect future systems to deploy multi-sensor unmanned air vehicles (UAVs). Similarly, the ground-based sensors can be deployed on *multiple* robots. In the proposed research we will concentrate on algorithms that would adaptively direct such systems, based on the inversion results.

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Final Report: ARO MURI on
Adaptive Multi-Modality Inverse Scattering
for Targets Embedded in General Stochastic Environments
ARO-43583

PI: Lawrence Carin
Electrical & Computer Engineering Department
Duke University
Durham, NC
Program Period: 2002-2007
ARO PM: Dr. Russell Harmon, DARPA PM: Douglas Cochran

1. Most Recent Program Review

Location: Springfield, VA
Date: January 30, 2008
Government participants:

- Russell Harmon, ARO
- Tom Broach, NVESD
- Anders Sullivan, ARL
- Karl Kappra, ARL
- Richard Weaver, NVESD
- Jay Marple, NVESD

2. Program Objective

The program addressed development of adaptive detection and classification algorithms for multi-modal inverse problems. The research focused on the general problem of detection and classification of targets surrounded by dielectric layers and stochastically distributed scattering centers. Within the context of this overarching theme, the program addressed the particular applications of detecting and classifying obscured ground targets, landmines, and subsurface structures.

In the research "inverse scattering" was defined broadly to represent an algorithm that infers the target and environmental characteristics using data from a multiplicity of active and passive sensors. The program considered two classes of inverse-scattering algorithms. One class was based on a direct use of the associated underlying wave equations, often employing a forward solver as an integral component of the inversion process itself. Methods such as reverse-time migration fall under this class of approaches. The second class of inversion schemes used the forward algorithm and available measured data for "training" a statistical model, and during the subsequent inversion the trained algorithm no longer need employ a forward solver. Bayesian and mutual-information-based algorithms fall under this latter class.

3. MURI Team Members

- Lawrence Carin, Duke University
- Leslie Collins, Duke University
- Qing Liu, Duke University
- Alfred Hero, University of Michigan
- Waymond Scott, Georgia Institute of Technology

- James McClellan, Georgia Institute of Technology
- George Papanicolaou, Stanford University

4. Accomplishments

- Adaptive classification algorithms for landmine sensing developed at Duke integrated within NITTEK radar system, and deployed in theater
- Electromagnetic induction system developed by Georgia Tech integrated within Army FCS system
- Transition of MURI personnel to Army (grad student Jay Marple now employed at NVESD)
- Software developed for modeling foliage-penetrating (FOPEN) radar has been transitioned to the DoD High Performance Computing Program (Duke)
- Duke optimal-search technology transitioned to DARPA ISP (integrating sensing and processing) program
- Duke and Michigan optimal sensor-management technology transitioned to DARPA PHD program (predicting health and disease)
- Duke signal processing technology transitioned for standoff detection of electronic circuits, with separate funding from I2WD
- Duke 3D inverse-scattering research transitioned to NIH for breast-cancer-detection research
- Michigan sensor-management approaches are being integrated into human in the loop data mining for bioinformatics applications
- Michigan collaborated with General Dynamics on Willow Run experiment for multi-modal tracking of dismounts and vehicles

5. List of Manuscripts Submitted/Published under ARO Support

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16. L.-P. Song, and Q. H. Liu, "GPR landmine imaging: 2D seismic migration and 3D inverse scattering in layered media," submitted, 2003.

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18. L. Li, J. He, Z. Liu and L. Carin, "MLFMA analysis of scattering from multiple targets in the presence of a half space," IEEE Trans. Antennas Propagat., vol. 51, pp. 810-819, April 2003.

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37. X. Liao and L. Carin, "Application of the theory of optimal experiments to adaptive electromagnetic-induction sensing of buried targets," submitted to IEEE Trans. Pattern Analysis Machine Intelligence

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6. Patents

None